Hybrid III-V-on-Si Laser with Ultra-low Energy Consumption

Taghizadeh, Alireza; Mørk, Jesper; Chung, Il-Sug

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DTU Fotonik
Department of Photonics Engineering

Hybrid III-V-on-Si Laser with Ultra-low Energy Consumption

Alireza Taghizadeh*, Jesper Mørk, Il-Sug Chung
Department of Photonics Engineering (DTU Fotonik), Technical University of Denmark, DK-2800 Kgs. Lyngby
**alitag@fotonik.dtu.dk*

Motivation

• Optical Interconnect: low power consumption and high speed modulation for on-chip interconnection technology
• Main goal: Development of a comprehensive laser simulator to investigate different micro-laser structures

Intel Light Peak interconnect

IBM vision for 2020

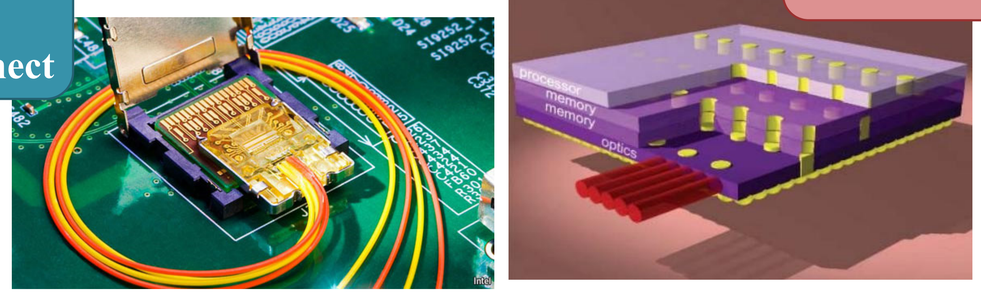
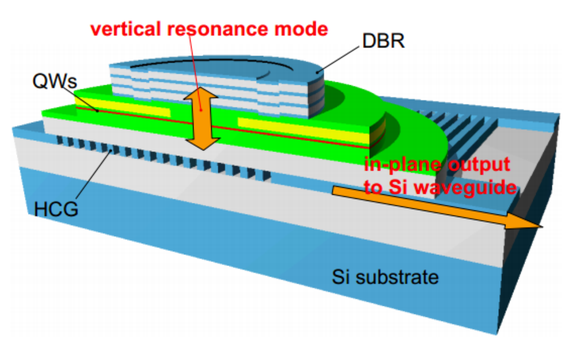


Figure 1. Schematic of the future photonic networks.

Interesting Device Structures

1) Different VCSEL structures with DBR and/or PCM mirrors
2) Resonance cavity enhanced photodetectors
3) Photonic crystal based waveguides and devices



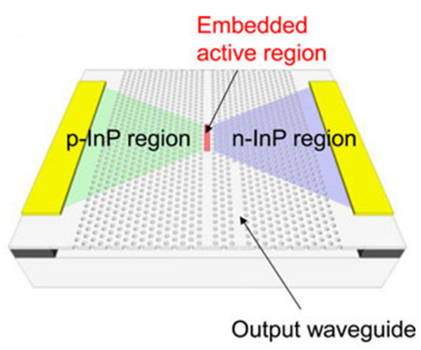


Figure 2. Schematic of various laser structure.

A Laser simulator is required

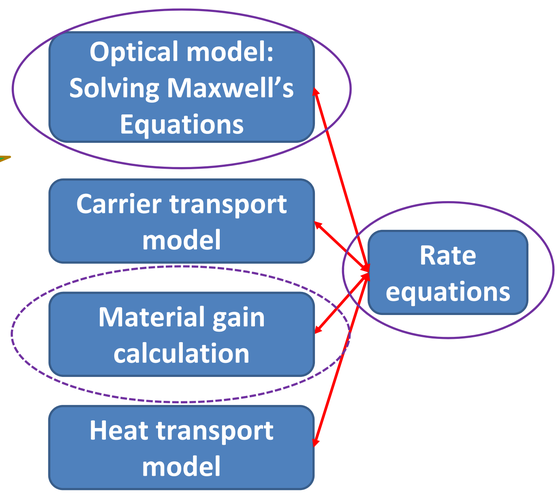


Figure 3. Laser simulator different part.

Fourier Modal Method (FMM)

• Spatial frequency domain method (Fourier space)
• Different names: Differential method, RCWA, Plane-wave method, …
• All electromagnetic quantities are expanded in Fourier series
• Layered discretization, Expansion on modes of layers

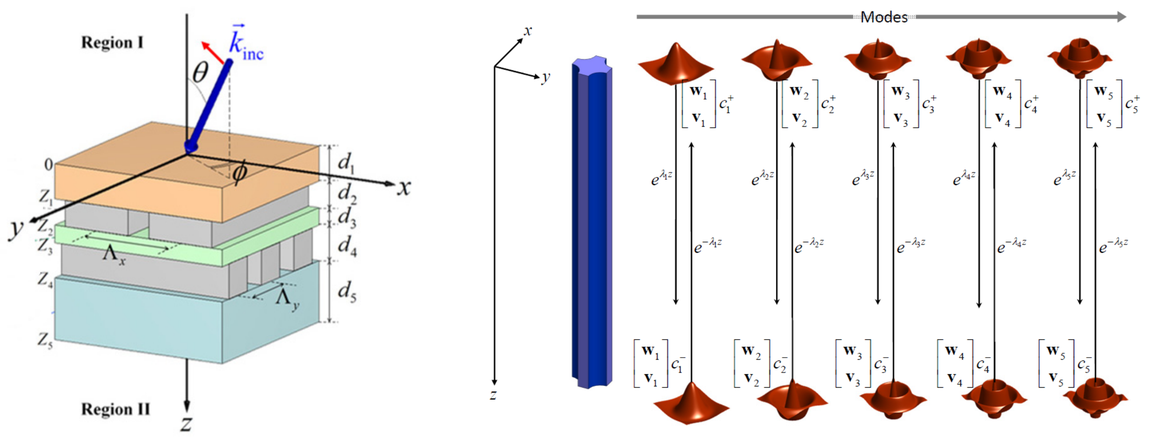


Figure 4. Schematic of a typical device structure and FMM procedure.

Rate Equation

• Model the electrical and optical performance of a laser
• Calculate carrier and photon density in different modes
• Analyze dynamics of the laser
• We used modal model to solve these equations

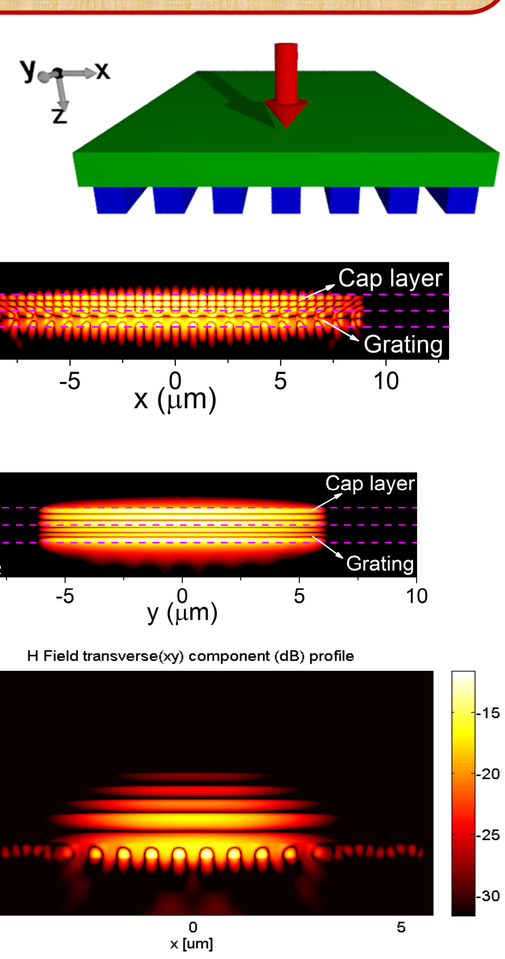
$$\frac{\partial N(x_1,x_2,t)}{\partial t} = \frac{\eta_i I(x_1,x_2,t)}{qV} - \frac{N(x_1,x_2,t)}{\tau_N} + D_N \nabla^2 N(x_1,x_2,t) - \sum_m G_m(x_1,x_2,t) S_m(t)$$

$$\frac{\partial S_m(t)}{\partial t} = -\frac{S_m(t)}{\tau_{sm}} + \frac{\beta_m \Gamma_m}{\tau_N A_m} \iint N(x_1,x_2,t)\mathrm{d}A + \frac{\Gamma_m}{A_m} S_m(t) \iint G_m(x_1,x_2,t)\mathrm{d}A$$

Simulation Examples

• A compact Hybrid grating resonator
• VCSEL with PCM mirror
• Conventional VCSEL with rectangular current aperture

3D Optical Solver



Rate Equation Solver

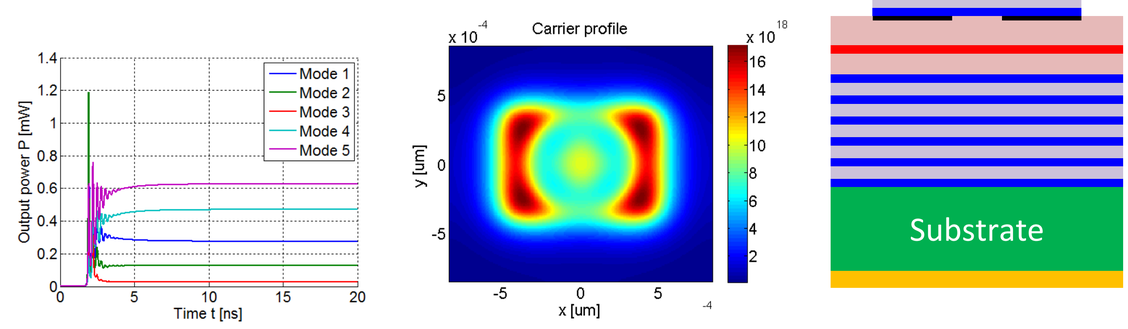


Figure 5. Several simulated structure and their results.

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